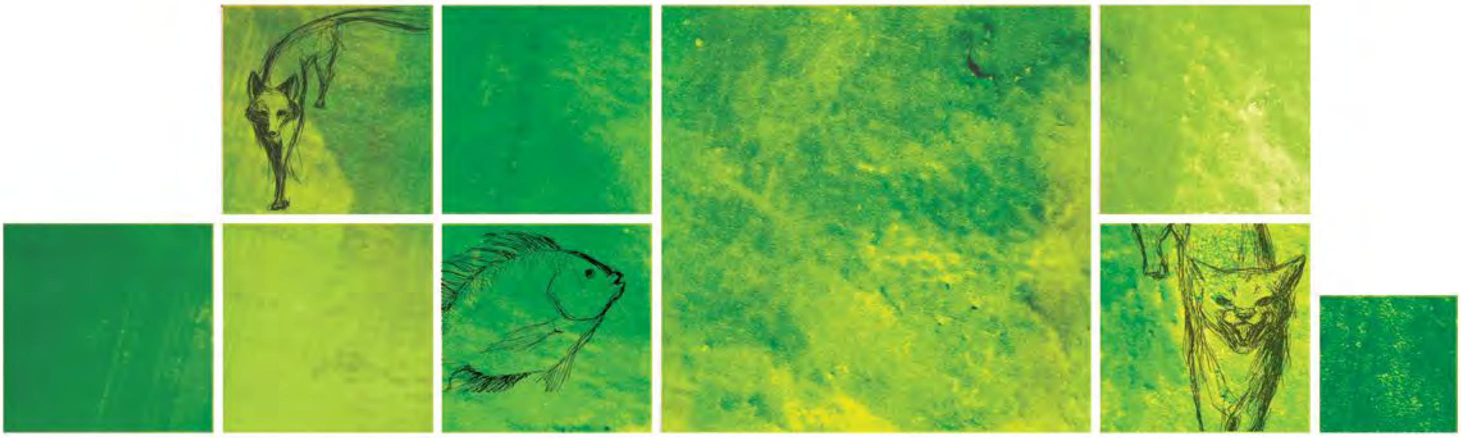

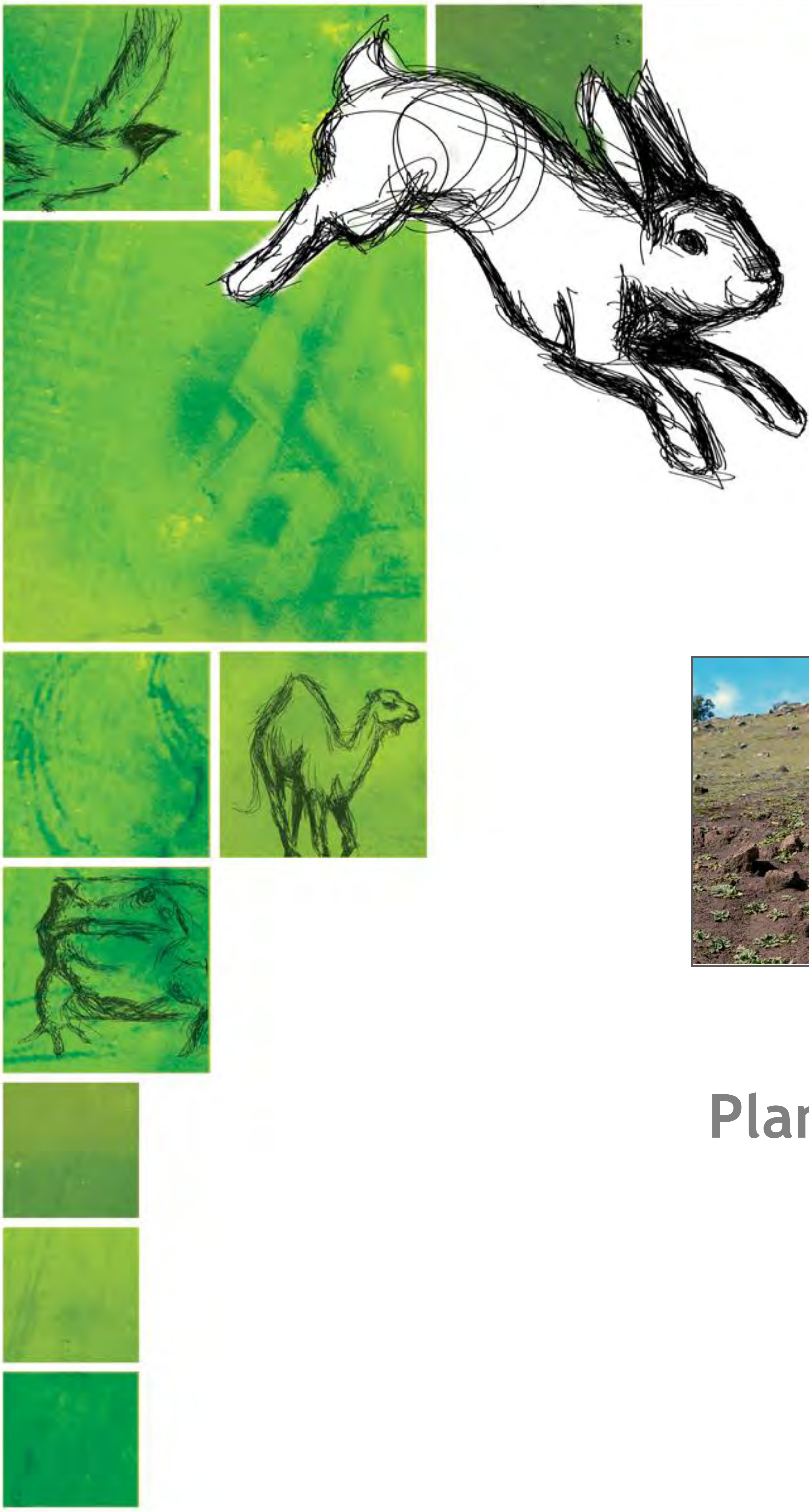

PESTSMART

Planning landscape-scale rabbit control

Brian D. Cooke

Invasive Animals CRC

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Brian D Cooke

Invasive Animals Cooperative Research Centre

University of Canberra, Kirinari Street,
Bruce, Australian Capital Territory 2617

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An IA CRC Project

Planning landscape-scale rabbit control

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Telephone: (02) 6201 2887

Facsimile: (02) 6201 2532

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Front cover photos (clockwise, from top): Warren-ripping demonstration at Lameroo (Brian Cooke), vegetation damage (Brian Cooke), land damage (Invasive Animals CRC).

Contents

Summary

Wild rabbits are increasing in numbers, apparently because the effectiveness of rabbit haemorrhagic disease (RHD) as a biocontrol is waning. This means that the $400 million in annual benefits gained from releasing the disease in Australia is slowly being eroded.

Once again, there is increasing reliance on mechanical and chemical rabbit control methods such as poisoning, warren ripping and fumigation not only for crop and pasture protection but also for conservation purposes. It is now generally acknowledged that even at low rabbit densities (fewer than 0.5 rabbits per hectare) the regeneration of the most palatable native shrubs and trees can be prevented. Wider landscape-scale rabbit control is needed, rather than the previous approaches that focused heavily on benefits to agriculture alone. This is particularly so in mallee-farming areas, where rabbits live mainly among relict natural vegetation on roadsides but obtain much of their food from adjacent crops and pastures.

Methods for removing rabbits are generally well researched and, if used together at the right time of year, can effectively control rabbits. New tools are also available, including a wide assortment of machines, such as log skidders and backhoes, which can be used for warren and rabbit harbour destruction while minimising damage to native vegetation.

Unfortunately, although RHD kept rabbit numbers low over the decade or so, there has been a major skill loss among land managers, and new approaches are needed to restore capacity and effectively control rabbits. These approaches include greater use of specialised contractors and machinery and additional training and schemes that encourage individual land owners and managers to control rabbits on public road reserves.

Few land managers have the skills necessary to recognise rabbit impact on natural vegetation, and so educational material to help assess rabbit damage has been produced. This will help develop a properly integrated landscape approach to rabbit control. Nonetheless, future work also needs to include proper planning of human resources and budgets to overcome current inefficiencies in rabbit control and to control the animal on a wider scale. Tools such as economic decision models are proving useful in establishing a framework for implementing rabbit control programs and assessing progress. Such tools reinforce the need to use integrated rabbit control methods. That is, after rabbit numbers become at low ebb myxomatosis and RHD have taken their toll, we need to use poisoning, warren ripping and fumigation in sequence during summer and autumn. This is when rabbits are more likely to take bait because pasture quality is poor.

Impediments to rabbit control exist, such as concerns over potential effects on other wildlife, or OH&S issues, which are often unnecessary. Such impediments must also be resolved if work is to be done on the scale needed to meet the economic and conservation objectives expected under the ideals of sustainability and long-term land use.

The concepts developed and issues raised in this report are important factors to consider in developing wider community-based rabbit control programs within the framework of natural resource management boards and their equivalents.

Acronyms and abbreviations

ANFO	ammonium nitrate and fuel oil (explosive)
CMA	catchment management authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ha	hectares
LHPA	livestock health and pest authorities
LPG	liquid propane gas
NRM	natural resource management
OH&S	occupational health and safety
RHD	rabbit haemorrhagic disease
RHDV	rabbit haemorrhagic disease virus
RLPB	rural lands protection board
SOP	standard operating procedures

1. Introduction

Rabbit haemorrhagic disease virus (RHDV) was brought into Australia as a biological control agent in the 1990s and proved highly effective in reducing rabbit abundance, especially in parts of Australia with a Mediterranean or semi-arid climate. In those areas, spotlight counts of rabbits commonly fell by 90% or more as the disease spread (Bowen and Read 1998, Mutze et al 1998). However, in cooler, more humid areas, disease impact was not so high (Saunders et al 1999, Richardson et al 2007). It is widely considered that with the introduction of RHDV, rabbit numbers were reduced to less than 40% of their former numbers Australia-wide (Henzell et al 2002). The annual economic costs of rabbits, estimated mainly from lost production in the wool and beef industries, fell from around $600 million (ACIL Economics 1996) annually to $200 million (McLeod 2004, Gong et al 2009). The $400 million cost reduction represented a major saving, although a troubling residual cost remained for the landscape. RHD enabled the first widespread regeneration of palatable shrubs and trees in inland Australia (Sandell 2006) since myxomatosis was introduced in the 1950s. In some instances, RHD resulted in the first effective regeneration of some native plant species since rabbits arrived.

The environmental benefits of removing rabbits remain unassessed in monetary terms due to difficulties in quantifying environmental assets and the associated benefits of rabbit removal. The benefits are likely to be high and are probably of equal ranking with agricultural damage. Rabbit impact on native vegetation and fauna is still poorly understood. However, the benefits will be greatly appreciated in the future as improved economic indicators for natural resources are developed.

Unfortunately, after a decade or so of relatively low numbers, rabbits are now increasing and the effectiveness of RHD is declining (Sandell 2006). This trend has been obvious since about 2002, and there is increasing evidence that rabbits may be becoming resistant to RHDV (Cooke and Elsworth unpublished data). This effectively means that rabbits are beginning to reverse much of natural vegetation recovery gained during the late 1990s even though more and more money is being spent on rabbit control each year. In the Hattah-Kulkyne National Park, for example, allocations for rabbit control increased from $35 000 in 2002 to $300 000 by 2007 (Sandell unpublished). In farming areas, the use of poisoned baits is increasing, and rabbit warren ripping and fumigation are also being used more frequently.

Although it is arguable that we still have a good range of techniques for managing rabbits to offset the decline of RHD, the need to revert to poisoning or warren ripping imposes additional costs on farmers, livestock producers and other land managers. The average size of farms has increased as has the average age of farmers (Australia 2020 Summit 2008), thereby reducing the physical capacity to tackle rabbit problems. It is also important to recognise that there have been other important changes in the 15 years since RHD was introduced. There has been a major loss of skills associated with generational change and the lack of necessity for direct rabbit control because rabbit numbers were being held low by disease. Based on the assumption that the rabbit had been beaten, there have been legislative changes and new policies (eg chemical handling, pesticide labelling and use, OH&S, animal welfare, cultural heritage) without much consideration of their cumulative consequences for carrying out rabbit control. Individual policies, although seemingly beneficial in their own right, add a new layer of complexity to rabbit control procedures, and these need to be taken into account when managing rabbits.

Even more importantly, the years when RHD kept numbers low demonstrated that a management goal of fewer than 0.5 rabbits per hectare is essential if our more vulnerable natural plant ecosystems are to be maintained. This is a difficult target to meet and means that we need highly capable land managers to properly look after natural vegetation on roadsides and other public lands including national parks. Society expects that native vegetation will be maintained for aesthetic, recreational and conservation purposes, and legislation at both federal and state levels encourages this.

On putting together these trends and observations, it has become clear that there is a widening gap between expectations and our capacity to meet these new objectives. A high level of rabbit control is needed to protect both natural assets and agricultural productivity, but there is often a limited capacity for action among land managers who are expected to put these ideas into practice.

To help bridge this gap, we must find new ways of approaching rabbit control. One idea is the use of an economic decision model to look at ways of handling rabbits in areas of high conservation value. This model effectively enables native vegetation to be valued in monetary terms, so that the costs and benefits of carrying out rabbit control can be better assessed. This report discusses many of the elements needed for the model before bringing them together in a framework for assessing progress in rabbit control.

The study focuses heavily on mallee areas of northwest Victoria and adjacent South Australia. The resurgence of rabbits is most obvious here, and it is also an area where rabbits commonly live among natural vegetation on road reserves yet obtain much of their food from adjoining farmland. This makes crop and pasture protection and native vegetation conservation part of the same problem to be solved. Despite this focus, the principles developed also apply to other farming areas of southeast Australia where landscapes are a similar mix of agricultural lands and remnant vegetation on reserves of various kinds. The approach outlined recognises that there is a shift in emphasis towards conservation and a need for rabbit control across a wider spectrum of land uses. As such, it is better attuned to the planning needs of regional natural resource management (NRM) boards and their equivalents.

Aim

This study aimed to develop a balanced regional approach to rabbit control and effectively counter the resurgence in rabbit abundance, by bringing together new ideas on managing rabbits to benefit Australian agriculture, the pastoral industry and biodiversity conservation.

Sources of information

This report has drawn heavily on a review of the literature on the impact of rabbits on agriculture and native vegetation, recent unpublished research, workshops, field demonstrations of effective rabbit control, economic decision models and epidemiological studies to plan for the future as the impact of RHD diminishes.

2. The current problem

Although rabbits are clearly not as abundant as they were before the introduction of RHD, a recent survey of roadsides, rail reserves, creek lines and farm woodlots in southeast Australia showed that rabbits are present on about half of the 220 sites visited. Nonetheless, clear regional differences were apparent: rabbits were found in only 30% of sites in south Queensland and east New South Wales, but they were encountered on 70% of sites in west Victoria and South Australia. Obvious damage to native shrub and tree seedlings was seen at about a quarter of all sites visited.

Rabbits are by no means restricted to areas where native vegetation predominates. Warrens are commonly found in irrigated areas along channel banks and on the edges of vineyards. They are surprisingly common in cemeteries, sports grounds, golf courses and school and university grounds where they cause severe damage to gardens and other amenities. A telephone survey of rangers from livestock health and pest authorities (LHPAs) in New South Wales (consisting of the former 46 rural lands protection boards, RLPBs) has provided a list of the most common rabbit problems (see Table 1).

Table 1. Results from a telephone survey of rangers from the 46 NSW rural lands protection boards (now known as livestock health and pest authorities) listing the impact of rabbits in different land-use areas and the number of respondents (or boards) who considered those impacts to be important in their area.

Land use	Examples of impacts cited	Number of RLPBs
Rural		
grazing	competition with sheep/cattle	37
cropping	damage to cereal, oilseed, soybeans	13
buildings	burrowing under wool and haysheds	9
horticulture	damage to olives, vegetables	9
viticulture	damage to young vines	7
forestry	damage to tree seedlings	5
other	warrens undermining railway lines	2
Conservation*		
landcare/mine restoration	destruction of planted seedlings	10
Urban/semi-urban		
home gardens/hobby farms	damage to gardens, amenities	38
sports/recreation areas	damage to golf links, caravan parks, school ovals	16
cemeteries	burrows under gravestones	7
buildings	burrows in industrial and school sites	5

* Does not include work contracted by NSW National Parks and Wildlife Service

The picture gained from New South Wales has been reinforced by information from other states, but there are some differences reflecting the emphasis placed on particular industries and interests in each state. For example, LHPA respondents in Victoria were less involved with conservation matters than Catchment Management Officers, but in South Australia rabbit impact on cereal cropping and viticulture was seen as being relatively more important than in other states.

The ‘RabbitScan’ project (http://www.feralscan.org.au/rabbitscan/), which sought information on rabbit distribution from the general public, confirmed that rabbits were a major issue on the urban fringes of all cities across southern Australia. This aspect of rabbit control has not been adequately addressed because of the largely agricultural focus on controlling rabbits, and yet the frustration expressed by many ‘RabbitScan’ participants (J Quealy, personal communication) shows that more work is needed to deliver better rabbit control in urban fringes.

3. Conservation ethics, sustainability and land stewardship

Ethically, we should be custodians of the land if we wish our descendants to be able to make productive use of it. This goal is often expressed in terms of sustainable development or conserving biodiversity. Put simply, this means that more should be done to take a wider view of land use and recognise that there are benefits from putting substantial effort into maintaining productive soils, improving our water resources and retaining vegetation. Global climate change and sequestering of carbon are significant issues here too, and options should be kept open so that appropriate action can be taken as needed. Within this broad picture, there are many other issues, including the control of animal pests and weeds that interfere with those actions.

In specific terms of rabbit control, it needs to be recognised that where roadside vegetation is dying out as a result of rabbits preventing regeneration, the dead and fallen trees will eventually decay and the carbon dioxide released in this process will contribute to the ever-increasing amount of carbon dioxide in the atmosphere. Certainly, roadside vegetation could be replaced by planting new trees and shrubs, and that is happening in some places, but it would be far more rational to retain the natural vegetation that is still present. Furthermore, the planting of new trees and shrubs occurs on too small a scale given the total size of the Australian continent. It also falls well short of replacing the natural ecosystems that previously existed. Australia has unique flora and fauna, and today many rare plant species only occur on roadsides and similar reserves. Roadside vegetation is also regarded as providing refuges, nesting places and corridors for the movement of native birds and, less frequently, mammals (Bennett 1988).

In mallee-farming areas, it is now expected that landscapes with remnant native vegetation on roadside and uncleared reserves should be conserved for aesthetic reasons, vegetation conservation, wildlife corridors and shelter belts for adjacent farmlands. At both Commonwealth and state levels, legislation has been put in place to encourage this. Examples include the federal *Environment Protection and Biodiversity Conservation Act 1999* and the *Victorian Flora and Fauna Guarantee Act 1988*. A publication entitled *Victoria's Native Vegetation Management: A Framework for Action 2002* guides management of all native vegetation across that state under the three principles of:

- avoiding native vegetation removal wherever possible
- minimising native vegetation losses where removal is unavoidable
- offsetting losses by replanting and improving the condition of existing native vegetation.

In this context, rabbit control can no longer be viewed simply as an economic problem of agricultural and pastoral land. A more wide-ranging approach must be taken to resolve rabbit problems across areas with different land uses, and it must involve the wider community.

4. Rabbit damage to agriculture and livestock production

Rabbits can heavily impact agriculture. They compete directly with livestock, encourage weeds and eat crops. Rabbit grazing is often measured in terms of 'dry sheep equivalents', and the exact equivalent has been established using various estimates (eg Short 1985). In general, it is considered that about 12 rabbits are equivalent to one sheep. However, some authors argue that in terms of changing pasture composition, by grazing out clovers, for instance, eight rabbits are equivalent to one sheep (Myers and Poole 1963).

It has been shown experimentally (Croft et al 2002) that rabbits severely deplete improved legume pastures, particularly subterranean clover pastures, and that grass cover increases in line with rabbit density. This effect is cumulative, and in the final year of the experiment cited above, pasture in the area where no rabbits were present included 31% legumes and 25.2% grasses, but the highest rabbit-density area had 6.2% legumes and 47.4% grasses. Indices of pasture biomass were highest in the zero-rabbits area and lowest in the treatment where rabbit density was 72 rabbits per hectare. More bare soil was evident where rabbit density was highest and damage generally increased with a progressive increase in rabbit numbers. When it came to wool production from the sheep that competed with the rabbits, the picture was less clear. Wool production was lowered where competition with rabbits was high, but the wool was also finer (ie lower micron rating) and had a higher value, offsetting the lower production to some extent (Fleming et al 2002). Despite this, according to Vere et al (2004), rabbits impose annual costs on wool producers in the temperate areas of southeast Australia of $7.1–38.7 million. The calculated figures partly depend on seasonal variations in the numbers of rabbits present.

Crop damage has not been experimentally quantified in the same way as wool or meat production. It is often difficult to distinguish between rabbit damage and the suppression of crop growth resulting from competition with roadside vegetation, especially when the latter itself is complex. In close proximity to roadside vegetation, grain production may be reduced because of root competition. Deeper into the crop grain production may be better, particularly in dry years where these plants would be protected from wind and so suffer less from water loss and sand blasting (Nuberg et al 2002).

Where rabbits live on roadsides but seek food in adjoining paddocks, crop damage is often obvious as grazing 'halos' in the immediate vicinity of rabbit warrens. This is often most noticeable when damage to sprouting crops promotes weeds and again just before harvesting when rabbits nip off stalks to reach grain (Cooke 1981). In these areas, the area in which the crop has been depleted can be visually estimated along a paddock edge and tallied up to estimate the hectares of crop lost.

5. Rabbit damage to native vegetation

Most people are completely unaware that just a few rabbits can have a major effect on native plant ecosystems. Even today, despite rabbit numbers being much lower than before the release of RHDV, rabbits substantially reduce natural regeneration. Furthermore, the recent survey mentioned in Section 2 showed that this is a widespread problem. There is a growing list of plant species known to be severely affected by rabbit browsing in at least some part of their natural range (Table 2).

Table 2. Examples of tree and shrub species from semi-arid Mallee and Wimmera regions reported to be affected by rabbit browsing.

Scientific name	Common name	Reference
Acacia ligulata	umbrella bush	Munro et al (2009)
		Lange and Graham (1983)
Acacia oswaldii	umbrella bush or nelia	Auld (1995)
Alectryon oleifolius	rosewood/bullock bush	Sandell (2006)
Allocasuarina verticillata	sheoak	Cooke (1987)
Allocasuarina leuhmannii	buloke	Sandell (2006)
Allocasuarina pusilla	dwarf sheoak	Cramer (unpublished)
Banksia marginata	silver banksia	Cramer (unpublished)
Bursaria spinosa	sweet bursaria	Bird and Mutze (unpublished)
Callitris glaucophylla	white cypress	Johnston (1968)
Callitris gracilis	slender cypress	Sandell (2006)
Dodonaea attenuata	hop bush	Sinclair (2005)
Eremophila longifolia	weeping emu bush	Sinclair (2005)
Eremophila sturtii	turpentine	Sinclair (2005)
Eremophila alternifolia	narrow-leaved emu bush	this study
Hakea leucoptera	needlebush	Sandell (2006)
Leptospermum myrsinoides	heath tea-trees	Cramer (unpublished)
Maireana pyramidata	bluebush	Sinclair (2005)
Myoporum insulare	boobialla	Gillham (1963)
Myoporum platycarpum	sugar wood	Sinclair (2005), Sandell (2006)
Rhagodia spinescens	creeping saltbush	this study
Senna nemophila	cassia	Silander (1983)
Senna artemisioides subsp. coriacea	cassia	Sinclair (2005)
Senna artemisioides subsp. petiolaris	cassia	Sinclair (2005)

Until now, the need for rabbit control to protect native vegetation on roadsides has often been confused by lack of a clear method of assessing the threat posed by rabbits. That rabbits suppress regeneration has often been thought to be relatively unimportant because many trees and shrubs are long-lived. Nonetheless, this takes no account of what happens to relatively short-lived palatable plant species in plant communities. A good example is the *Acacia* understory on roadsides that can thin out owing to lack of recruitment and disappear, yet its absence is barely noticed.

By simplifying things and asking about the immediate process of rabbit browsing, rather than trying to predict the longevity of vegetation, we can at least say whether or not rabbits are inhibiting the natural process of regeneration in roadside ecosystems. This is a useful first step in deciding whether rabbit control is warranted. Of course, it is also useful in gauging, within a year or two, whether rabbit control programs on roadsides have been successful. The booklet *Rabbits: A Threat to Conservation and Natural Resource Management* (Cooke et al 2008) provides a quick and easy method to help land managers decide where rabbit control is needed to protect native vegetation.

Relationship between rabbit density and damage to native vegetation

By assessing rabbit damage to vegetation and relating this to rabbit abundance as measured by the amount of rabbit sign (eg faecal pellets and active warren entrances), it has been possible to derive a simple relationship between the natural ability of roadside vegetation to regenerate and rabbit abundance. Indeed, it is surprising how quickly the capacity of vegetation to regenerate declines as rabbits become more plentiful. Nonetheless, not all vegetation is equal. Intact natural vegetation that includes many plant species obviously has better prospects for regenerating than degraded vegetation where weed invasion or previous overgrazing has decreased its diversity. This is illustrated by the three curves in Figure 1, which effectively represent vegetation of high, medium and low regenerative and conservation value.

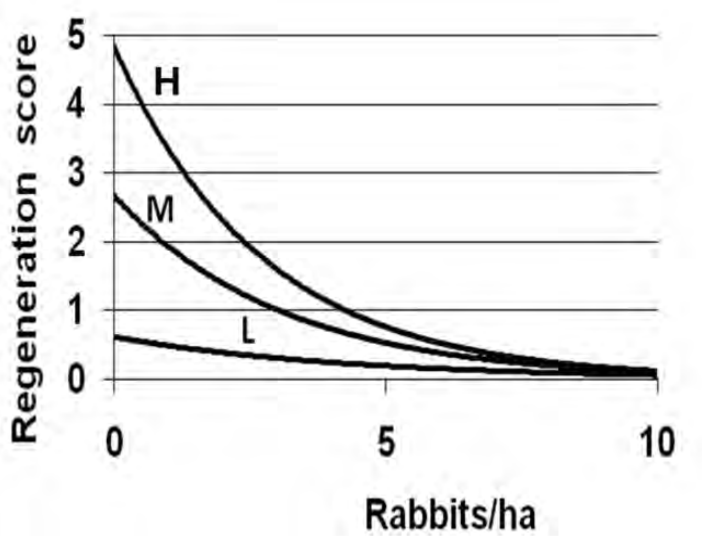

Figure 1. The three curves derived in this figure indicate how capacity for regeneration of native vegetation changes in relation to rabbit density. The three curves show the anticipated responses of vegetation of high (H), medium (M) and low (L) ability to regenerate following removal of rabbits.

Putting a value on native vegetation

The value of native vegetation in this context can be taken as the replacement or replanting cost of roadside vegetation in mallee areas of northwest Victoria. This amounts to about $2100 per hectare (C Brady, personal communication). This value is conservative because it does not take account of ongoing maintenance, such as weeding and pest control over the first few years when plants are becoming established. It also neglects that replanting of trees would be unlikely to fully replace previous plant diversity or recreate the ecosystems supported by the former vegetation.

Not everyone would necessarily evaluate remnant vegetation in the same way, and if rabbits are not controlled and native vegetation is slowly lost owing to lack of recruitment, there is no clear penalty or cost for having allowed this to happen. On that basis, it is arguable that native vegetation should not be so highly valued. Nevertheless, given the strong policies for encouraging the retention of remnant vegetation as well as subsidised replanting programs by volunteers, the costs of replanting should provide an acceptable starting value. After all, the main aim of rabbit control should be to ensure that woodland remnants are self-sustaining; replanting should be a last resort and implemented only when vegetation becomes heavily degraded.

6. Cost-effective methods of rabbit control

The rabbit control methods used today were first developed in the 1890s. Even then, poisoning, warren destruction and fumigation were commonly used. Nonetheless, it is important to recognise that there have been many major improvements in the application of these methods. Research by CSIRO and state agencies during the 1960s and 1970s assessed cost-effectiveness and removed much of the folklore that had built up around different methods of control. The advocacy of ‘1080’ (sodium fluoroacetate) poison to replace strychnine was one example. This became even more important after researchers in Western Australia showed that this compound occurs naturally in some native shrubs and that some native mammals and birds are relatively resistant to it. Likewise, free feeding of rabbits several times, at two to three day intervals before laying poison baits, was shown to greatly enhance the percentage killed. Much of this research has been conveniently summarised in the book *Managing Vertebrate Pests: Rabbits* (Williams et al 1995; also available online at http://www.feral.org.au/managing-vertebrate-pests-rabbits/).

Research also showed that using a combination of rabbit control treatments was much more cost-effective than using one method alone (eg Cooke 1981; Williams and Moore 1995). The cost-effectiveness of combined treatments has been well analysed and, with updating to present-day costs, those earlier experimental results still provide a sound basis for estimating likely expenditure on current rabbit control programs. Rabbit control among natural vegetation on roadsides currently costs about:

- $52 per hectare for 1080 poisoning using oat baits
- $40 per hectare for warren ripping where there are moderate infestations of rabbits
- $58 per hectare for fumigation with aluminium phosphide tablets (eg Phostoxin®).

Nonetheless, when different rabbit control methods are used in combination, there are some obvious savings. For instance, after ripping there are generally few holes to treat with fumigants.

Poisoning is best done in summer. Rabbits are relatively few in numbers then because kittens born towards the end of the breeding season die off as food quality declines and myxomatosis and RHD take their toll. Adult rabbits are also much more likely to take baits because there are few alternatives to the dry, low-quality straw of natural pastures and crop stubble. Likewise, ripping is best done when the soil is dry and becomes powdery enough to flow into the deepest parts of the warren. Fumigation, on the other hand, is best done when there is some moisture in the soil because wet soils are less porous and slow the escape of fumigant gases. For the widely-used fumigant aluminium phosphide (Phostoxin® or Gastoxin®), soil moisture also stimulates the release of phosphine gas and makes it easier to pack warren entrances with soil to tightly seal them. It makes good economic sense to poison rabbits and rip warrens in summer and follow up with fumigation as the first autumn rains wet the soil again.

Warren ripping is undoubtedly among the most cost-efficient ways of controlling rabbits, especially where warrens are in open ground. Unlike some other control methods that have remained largely unchanged for many years, there has been constant innovation and enhancement of ripping practices, and this has improved effectiveness and kept costs from increasing. Machines now used range from small tracked 'Bobcat' backhoes fitted with tines to enable warren destruction among dense roadside vegetation, to large 'log skidders' weighing up to 13 tonnes and fitted with a scrub rake that can rip regardless of whether the machine moves forward or backward. These latter machines are of course more suited to use in open woodland or pastures.

Although large machines like bulldozers cost more to run per hour than smaller machines, they rip more warrens more thoroughly in a set time and usually cost less 'per warren destroyed'. Likewise, the innovative use of backhoes for destroying warrens among native trees and shrubs allows work to be done in areas where tractors would cause severe vegetation damage in gaining access to the warrens. A 30-tonne backhoe in southwest Victoria enabled the removal of rabbit warrens located among basalt outcrops (old lava flows) of the Stony Rises. A review of warren-ripping costs in 2009 showed that, at rates then-used by contractors, ripping generally cost between $10 and $20 per warren.

Other methods of rabbit control include explosive devices of various kinds. These range from general explosives, such as a mixture of ammonium nitrate and fuel oil (ANFO), to liquid propane gas (LPG) or oxygen-fuelled explosive devices, such as 'Rid-a-rabbit'. The use of explosives and explosive devices may not be encouraged in all states and, as is the case for fumigation, such methods are labour intensive, and therefore, relatively expensive. The use of explosives like ANFO is even more costly, mainly because of the high price of detonators and detonator cord. Bruce (2001) found that the cost of blasting was in the order of $140 to $160 for each large warren destroyed.

Operators of LPG/oxygen-fuelled devices suggest that it costs about $10 to treat an average warren — about the same as warren ripping. However, destruction of warrens is often incomplete so the real efficiency of these devices is likely to be much lower than that of ripping. A proper economic assessment of their effectiveness is still required despite their widespread use. Explosives and explosive gas devices should not be used as a first means of treatment of warrens in open ground because warren ripping is cheaper and more effective for that purpose. Their greatest potential and usefulness is likely to lie in clearing rabbit warrens from dense native heath vegetation (Bruce 2001) where heavy ripping machinery would cause major vegetation damage.

Shooting is not a useful control measure although often promoted on the premise that 'shooting a rabbit must be of some benefit'. Night 'spotlight' shooting mainly takes subadult and adult rabbits. Numbers of shot juvenile rabbits and kittens form a disproportionately low element compared with their true abundance in the population. This means that during the rabbit breeding season the vast majority of rabbits are not even seen, let alone shot.

In assessing any control method or combination of methods, it is essential to check whether or not it provides the most cost-effective way of reducing rabbit numbers to levels where they cause little harm. Even if a lot of rabbits are killed, this is not in itself a measure of success. Rabbit numbers must be reduced to low enough levels that crops are well-protected and natural vegetation is able to regenerate and function as a natural system.

7. Rabbit populations: capacity to recover from control operations

Even though the effectiveness of RHD is in decline, it still limits the capacity of rabbits to recover quickly when additional control activities are carried out. Prior to the spread of RHD, it was possible for rabbits to regain high numbers within 12 months of a 1080-poisoning campaign. At present, with the slower recovery time, post-RHD rabbit control programs usually have longer-lasting results.

This understanding has paid off particularly well for those who thoroughly ripped warrens when rabbit numbers were held low by RHD. Populations still remain low in those areas, but have increased substantially in areas left unripped (McPhee and Butler 2010). In calculating costs and benefits of present-day rabbit control programs, the slower recovery of rabbit populations is normally taken into account based on the rates seen in the field over the last few years (eg Sandell 2006 unpublished).

In developing the economic decision model described below, we have taken into account the slower rate of rabbit population growth in the post-RHD era.

8. Economic decision model

In conjunction with two economists with specific interests in agriculture and conservation, we have developed an economic decision model that brings together much of the information listed above (Cooke et al 2010). It considers the cost-effectiveness of different combinations of rabbit control on a computer-modelled rabbit population and then considers the likely gains or losses to the value of native vegetation based on the assumption that well-conserved, freely regenerating vegetation has a value of $2100 per hectare. Vegetation that has lower capacity to regenerate because of rabbit browsing is given a proportionally lower value. However, that value increases rapidly if rabbits are adequately controlled and the vegetation is able to freely regenerate again. Nonetheless, as shown in Figure 1, not all vegetation shows the same regenerative capacity and this variation was taken into account by considering the costs and benefits of rabbit control in vegetation with high, medium and low capacity to regenerate.

The model was used to determine the optimum combinations of treatments to reduce rabbits, and some of these results are shown in Figure 2. A single treatment, such as poisoning, is not very effective, but combined with other treatments, can bring rabbit numbers low.

We then simulated the effects of applying the optimum combinations of rabbit control treatments over 15 years to determine long-term costs and benefits. An example of the results obtained is shown in Figure 3 although the model itself was run 1000 times using a Monte-Carlo simulation to give some indication of the variation in results that could be expected in treating different roadside areas.

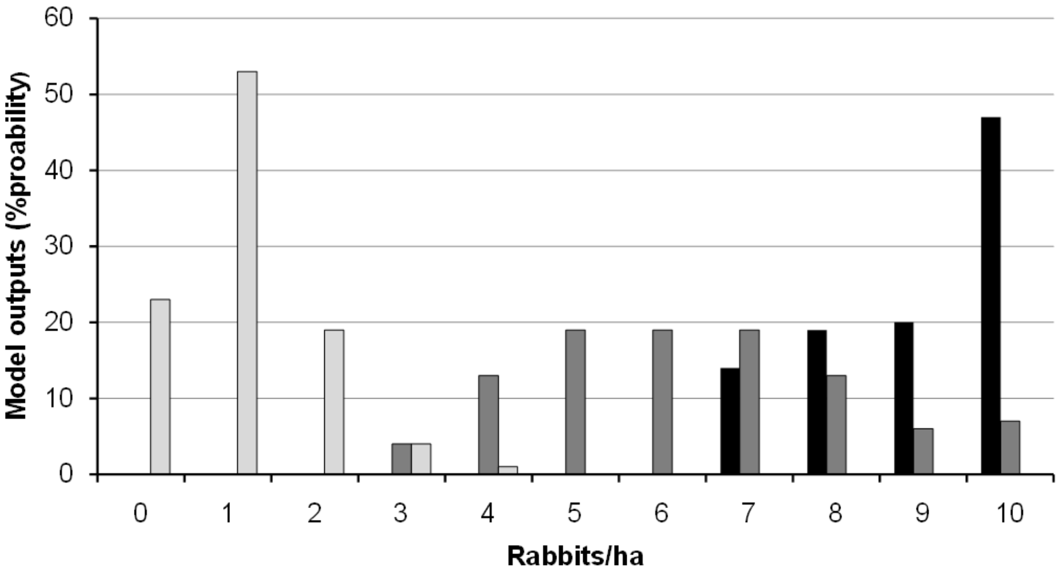

Figure 2. Model predictions, based on 1000 simulations, of the likely abundance of rabbits (rabbits/ha) just one year after treatment of an initial rabbit population of five rabbits/ha when: no action is taken (■ BLACK SQUARE), following poisoning alone (■ DARK GREY SQUARE), and following a combination of poisoning, ripping and fumigation (□ PALE GREY SQUARE).

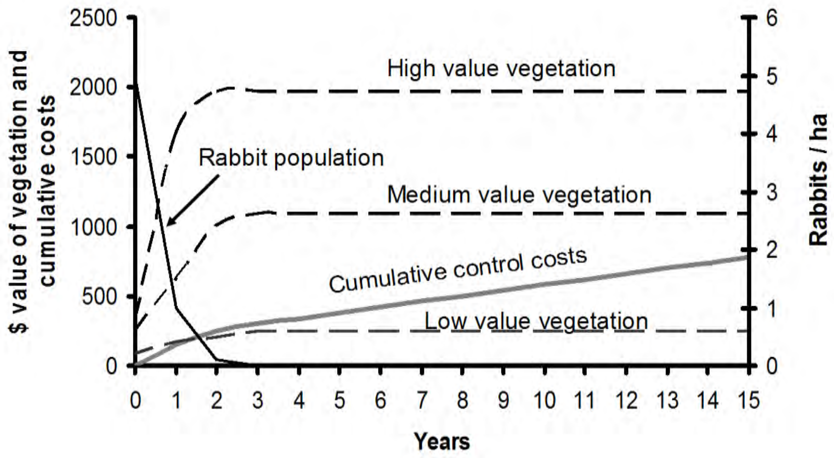

Figure 3. Model output showing how vegetation value increases as the rabbit population is brought to very low levels. Vegetation with a high capacity to regenerate (high value vegetation) and moderate capacity to regenerate give better returns compared with the cumulative cost of rabbit control than vegetation that has low capacity to regenerate.

By analysing rabbit impact on native vegetation in this way, it has been possible, for the first time, to reach some broad conclusions and develop policies on rabbit control for conservation purposes. Importantly, the model reinforces the idea that a combination of all three treatments — poisoning, ripping *and* fumigation — is essential for removing rabbits from among roadside vegetation. It is only when rabbit numbers fall low (less than one rabbit per hectare), that it is acceptable to shift to ripping and fumigation, and then annual inspection and fumigation alone as numbers are brought to extremely low levels (Table 3).

Table 3. Recommended treatments at different levels of summer-time rabbit infestations among vegetation with low, medium and high capacity to regenerate. Critical points are indicated where treatment can be changed to more economical alternatives as rabbit numbers decrease.

Population	**Roadside vegetation regenerative capacity**		
(rabbits/ha)	**low**	**medium**	**high**
0.00	nil	nil	nil
0.25	fumigate	fumigate	fumigate
0.50	fumigate	rip + fumigate	rip + fumigate
1.00	fumigate	rip + fumigate	rip + fumigate
1.25	nil	rip + fumigate	poison + rip + fumigate
1.75	nil	poison + rip + fumigate	poison + rip + fumigate
10.00	nil	poison + rip + fumigate	poison + rip + fumigate

The model also raises some other important concepts. One example is the clear recommendation that money is best spent on protecting high- and medium-quality native vegetation from rabbit damage, rather than removing rabbits from severely degraded habitats that have mostly lost their regenerative capacity. This is clear from Figure 3 where the cumulative costs of control over 15 years are shown in relation to the value of the vegetation. In economic terms, there is a substantial benefit to protecting readily regenerating vegetation, a smaller benefit for vegetation that shows a moderate response after rabbit control and a net loss in adopting a rabbit management program for poorly regenerating vegetation. Of course the benefits may change, depending on the actual value we place on vegetation, but it still follows that it pays to protect the best-quality natural vegetation in the first instance. It is also important to remember that protection of natural vegetation is not the only consideration. Rabbit control in areas where natural vegetation is degraded may still be essential to protect crops sown on adjacent lands or replanted tree and shrub seedlings.

Although the model is complex, the main outcomes can be summarised fairly simply, especially regarding policy setting and planning. Where funds are limited for rabbit control, it is important to use the most cost-efficient control methods. The model reinforces the essential concept of:

- using a combination of poisoning, ripping and fumigation to quickly bring rabbit numbers down
- then holding them at low levels using less expensive control combinations.

In this way we minimise expenditure and quickly maximise the value of the roadside vegetation. The value placed on readily regenerating vegetation is considerably higher than the cumulative costs of control. So, it is better to direct limited resources into protecting vegetation in this class rather than spending money on degraded vegetation in the hope that it might slowly recover.

Using these ideas, it should be possible to better plan rabbit control at a district level and direct work to areas where it is most needed, and at the same time recommend the methods to be used for maximum efficiency within a given budget.

Verifying the economic decision model

Lameroo demonstration site

We developed the economic decision model using the best estimates of rabbit control costs available in 2008. Since then, we have used a demonstration trial near Lameroo, South Australia to confirm whether or not those costs were realistic. We maintained detailed estimates of all costs during the project for this purpose. The main conclusions were:

- Poisoning of rabbits cost less than estimated by the economic model, at $36/ha compared with $52/ha. This was partly because poison was laid only in paddocks adjacent to the road and not along the roadside as well.

- The cost of destroying rabbit warrens using a Bobcat backhoe averaged about $69/ha, ranging from $35 to $117/ha. This was generally higher than the estimate used in the economic model ($40/ha) but reflects the difficulty of accessing warrens among scrub on steep sand drifts on the roadside. Figure 4 illustrates why costs of warren destruction can be high.
- Fumigation costs as calculated for the roadside were $56/ha, of which about $40 was spent on searching for reopened warrens. This figure is similar to the estimate used in the economic model, which included $40 in annual inspection costs and $18 spent on materials and fumigation time.

Figure 4. Warren ripping using a backhoe near Lameroo. Steep sand ridges and dense vegetation make access to warrens difficult, but warrens were destroyed without damage to the mallee eucalypts.

On the Lameroo site, poisoning, warren ripping and fumigation were effective in combination, leading to a 90% reduction in total warren entrances per hectare. Nonetheless, if used warren entrances are considered, this initial treatment only decreased rabbits from an estimated 10 rabbits/ha to about one rabbit/ha. This is a reasonable result but still is not completely effective in terms of the limit that some of the more palatable plant species can tolerate. This is also close to the decision point developed in the model suggesting when we could switch from ‘poison + rip + fumigate’ to ‘rip + fumigate’. Owing to the difficult terrain of the site, which included steep sand hills and dense scrub, field practitioners felt that another round of work would be needed in the following summer to reduce rabbit numbers to levels where there could be some confidence of keeping them low with minimum effort.

To gain maximum cost efficiency in rabbit control and vegetation benefits over a long period (15 years is used in the model), it is important that high initial costs of rabbit control are offset by low costs in later years.

In summary, the results of this trial generally fell within the expectations from the economic decision model. We are subsequently more confident that it provides a workable framework, not only for planning and evaluating specific rabbit control projects, but also for deciding where limited budgets would be best spent for conservation purposes.

Telopea Downs

At Telopea Downs, Simone Cramer from the University of Melbourne (unpublished report) showed that seedlings of native silver banksia (*Banksia marginata*) and heath tea-tree (*Leptospermum myrsinoides*) were more abundant in areas where rabbit warrens had been ripped than on adjacent unripped areas. Dwarf sheoak (*Allocasuarina pusilla*) only regenerated on sites where rabbit numbers had been substantially reduced. This verified that regeneration of native vegetation provides an easily acquired measure of the effectiveness of roadside rabbit control work. It also showed that the protected resource had gained value along the lines assumed in the economic decision model. The capacity of vegetation to regenerate was ranked as about 0.25 (on a scale of 0–5) in areas where rabbits were abundant (ie the vegetation had a nominal value of [0.25 x $2100]/5 = $105/ha). Where rabbit numbers were reduced by warren ripping, it significantly improved to 1.25 (a nominal value of [1.25 x $2100]/5 = $525/ha).

Although the economic decision model is by no means fully developed, it provides a useful framework for bringing together a wide range of ideas to help plan and assess future rabbit management. In a wider context, the control of rabbits to prevent native vegetation damage is also certain to keep rabbits well below levels at which they cause significant damage to adjacent crops and pastures.

9. New approaches for a changing scene

Many farmers no longer have small tractors that can be used among trees. Increasingly, this means that ripping must be done by contractors with appropriate machinery. The hire costs range from about $70 to over $120 per hour including the driver, and often include the wages of a person on foot or on a motorbike to direct the machinery when ripping. This person, referred to as a ‘spotter’, helps find warrens not readily seen from the cabin of the ripping machine and checks to see that warrens are thoroughly ripped.

Many landholders are not prepared to pay these rates without knowing something about the number of warrens that can be ripped in an hour. They also often prefer to see the achievable results demonstrated.

Nevertheless, there may be other ways of encouraging the uptake of innovations and maximising efficiency at a community level. In the Lameroo area in South Australia, NRM board staff have successfully controlled rabbits on roadsides using a program in which farmers poison rabbits, often using bait layers hired from the board, but the costs of specialised machinery for ripping are subsidised. These sorts of agreements are useful in reducing rabbits to levels where both crops and roadside vegetation are protected. Many farmers think they should not bear the full costs of caring for roadside vegetation, seeing it as a community asset despite the benefits of having fewer rabbits on their farm edges.

Other incentives include taxation offsets for this kind of activities. Under the *Income Tax Incentives Act 1997* (Subdivision 387-A), expenditure on preventing and treating land degradation is eligible for a rebate or deduction. This includes:

- erecting a fence (including an extension, alteration or addition to a fence) primarily and principally to exclude animals, such as rabbits, from an area affected by land degradation; to prevent or limit the land degradation extending or becoming worse; and to help reclaim the area
- eradicating or exterminating pest animals, such as rabbits, from the land.

These incentives are aimed at encouraging landholders to run rabbit control programs. They may also simplify the coordination of control programs across lands of different tenure.

10. Improving rabbit control

Skills for rabbit control have been lost over time owing to generational change and because RHD kept rabbit numbers low for almost 15 years, reducing the need for land managers to keep pace with new developments. In addition, new skills are needed to control rabbits at a landscape level. This is particularly so because many highly skilled conservation managers have a real ‘blind spot’ when it comes to observing rabbit impact on native ecosystems.

Recent experiences in the Hattah-Kulkyne National Park show that land managers did not recognise the growth of rabbit populations since their post-RHD low points. Action was finally taken when rabbits began heavily damaging naturally-regenerating seedlings in threatened pine–bulloke woodlands. One response was to put tree guards around small numbers of regenerating tree seedlings, rather than running an effective rabbit control program to benefit the whole ecosystem. That is, the initial response fell well short of what was needed to resolve the problem. A shift in thinking from crisis management of rabbits towards a strategic rabbit control program to maintain functional ecosystems was needed. That change has been seen and a robust rabbit control program has been put in place with a management objective of keeping rabbits below 0.5 rabbits per hectare (Sandell unpublished).

A broad approach to rabbit control needs wide organisational backing and should not be the sole responsibility of local land managers. Budgets need to be adequate to do appropriate work at the right time of year, and planning needs to take into account issues such as staff availability at those times. If staff are on standby for bushfire duty, for example, we need contractors to complete scheduled rabbit control work. Rabbit control should not be treated as something that might be done if finance or staff availability permits because rabbits destroy ecosystems irrespective of other timetables. We also need to move towards using highly skilled contractors with appropriate machinery for rabbit control, rather than duplicating equipment and providing rabbit control training across the whole community.

Nonetheless, there is still a need to train supervisors and others who must plan local programs and ensure that contractors are working efficiently. These supervisors also need to recommend the best methods and policies for rabbit control in their region and back up their support staff and contractors by defending well-thought-out actions where conflicts arise. It is important that issues, such as animal welfare or OH&S, do not derail the economic or conservation objectives of rabbit control. In short, a high level of professionalism is needed to ensure the job is done cost-effectively, problems are resolved and innovative approaches are taken up. Facilitating, rather than regulating field operations, should be the rule.

Moreover, there is little point in ignoring current problems in the hope that future biological control methods will resolve them. Although the current initiative by the Invasive Animals Cooperative Research Centre to investigate additional variants of RHDV will make some inroads, there can be no guarantee that additional virus variants will reduce rabbits below the critical point where natural regeneration becomes possible. Nor can there be guarantees that successes will be long-lasting. The introduction of new biological control agents involves prolonged, detailed research; seven years of research preceded the introduction of RHD into Australia, and the current project to assess new variants of RHD is expected to take three years.

11. Conclusion

RHD is losing its effectiveness, and rabbits are becoming more numerous in semi-arid and marginal cropping areas. This means that some of the $400 million in annual benefits of releasing the disease in Australia are being eroded.

Increasingly, there is a need for additional and more effective rabbit control to protect crops and pastures and to meet conservation objectives. This implies that a wider, landscape-scale approach to rabbit control is needed rather than previous approaches that focused heavily on agricultural economics alone. This is particularly so in mallee-farming areas where rabbits live mainly among relict vegetation on roadsides but obtain much of their food from adjacent crops and pastures.

Methods for removing rabbits are generally well researched. If used together, poisoning, warren ripping and fumigation can effectively control, and can even eradicate, the animal. This is particularly so when we use those methods at the right time of year to maximise their effectiveness. New tools are also becoming available, including a wide assortment of machines, such as backhoes, log skidders and bulldozers, which greatly assist in clearing out rabbits efficiently and minimising damage to native vegetation.

Despite these advances, there has been a loss of capacity among farmers and other land managers to effectively control rabbits, and novel approaches may be needed to solve this problem. In some instances it may be better to use highly skilled contractors with specialised machinery, rather than putting major resources into training or subsidising individual farmers. Indeed, some NRM boards are already developing policies where warren ripping is subsidised on the proviso that landholders first apply an effective poisoning program.

It is also apparent that many land managers — even within conservation agencies — lack the skills needed to understand rabbit impact on natural vegetation. This has been reflected in a lack of adequate response to increasing rabbit problems, even in areas where there are threatened plant communities. Educational material to help recognise rabbit damage among native vegetation has been developed as a step towards a properly integrated landscape approach to rabbit control. However, future work needs to include proper planning of human resources and budgets, rather than the piecemeal approach demonstrated so far in trying to improve rabbit control. An economic decision model that helps maximise cost-benefit outcomes is also under practical development. This provides a framework for rabbit control programs and helps determine progress on a regional scale.

The ideas set out in this document have resulted from discussions, field work and research involving operational land managers and professional contractors as well as researchers. The report, therefore, brings together a range of views that are relevant for developing wider community-based rabbit control programs, which will become increasingly important as the effectiveness of RHD wanes. It provides a framework that should be considered by NRM boards and other organisations with responsibility for rabbit control when developing or modifying their own regional rabbit control programs.

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